HIGH-PRESSURE METAL PIPE HAVING CONNECTING HEAD AND METHOD OF FORMING THE CONNECTING HEAD AS WELL AS SLEEVE WASHER FOR THE CONNECTING HEAD

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a high-pressure metal pipe having a connecting head and being formed of a thick-walled steel pipe of comparatively small diameter, as in the case of a high-pressure metal pipe used for a high-pressure fuel injection pipe approximately 4-20 mm in diameter and approximately 1-8 mm in wall thickness which is widely used as a fuel supply path in, for example, a diesel combustion engine, and to a method of forming such connecting head as well as a sleeve washer for such connecting head.

Description of the prior arts

This kind of high-pressure metal pipe having a connecting head as well as a method of forming the connecting head have heretofore been as follows. As shown in Figs. 6 and 7 by way of example, a truncated conical connecting head 12 has a seat surface 13 made of an outside circumferential surface formed at the end of a thick-walled steel pipe 11, and as shown in Fig. 8 by way of example, a truncated conical

connecting head 22 having an abacus-bead-like shape has a seat surface 23 made of an outside circumferential surface formed at the end of a thick-walled steel pipe 21. Each of the truncated conical connecting heads 12 and 22 is formed by buckling under axial pressure which is applied from the outside by a punch member, and at the same time a circumferential wall of each of the connecting heads 12 and 22 is expanded outwardly by buckling under such axial pressure, whereby an annular pocket 15-1 (Fig. 6) or 15-2 (Fig. 8) or an annular notch 15-3 (Fig. 7) which has an annular shape deep and large in cross section is formed around an inner circumferential surface of the connecting head 12 or 22. The high-pressure metal pipe is at present in use in the above-described state. Incidentally, reference numerals 14-1, 14-2 and 14-3 denote ring washers or sleeve washers which are respectively fitted to the backs of the connecting heads 12 and 22.

However, the high-pressure metal pipe having such a prior art connecting head as well as the method of forming the prior art connecting head have the following problems. One of the problems is that the deep and large annular pocket 15-1 or 15-2 or annular notch 15-3 (Fig. 8) which is formed in the inside of the connecting head allows a cavitation erosion to occur in the vicinity of the portion of the annular pocket 15-1 or 15-2 or the portion of the annular notch 15-3

owing to a high-pressure fluid during the use of the pipe, and the other problem is that there is a possibility that such a pocket or notch portion causes fatigue failure.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above-described problems of the prior art, and aims to provide a high-pressure metal pipe having a connecting head capable of solving the risks of cavitation erosion and fatigue failure in the inside of the connecting head owing to the contour shape of an annular pocket or notch which is formed in the inside of the connecting head during the working thereof, the contour shape of the annular pocket or notch having a shallow depth and a gentle cross section, as well as to a method of forming such a connecting head.

To achieve the above object, according to an aspect of the invention, there is provided a high-pressure metal pipe which includes a connecting head constructed to have a sleeve washer having a preferably cylindrical pipe-shaped portion which covers an outer circumferential surface of the connecting head of reduced diameter, the connecting head of reduced diameter having an outside circumferential surface formed as a truncated cylindrical or truncated spherical seat surface corresponding to a mating seat, and being provided on a connecting end portion of a thick-walled steel pipe

having a comparative small diameter, an annular concave groove which occurs in an inside portion of the connecting head during the formation thereof being shallow in depth and gentle in cross section. According to another aspect of the invention, there is provided a method of forming a connecting head for a high-pressure metal pipe which includes the steps of: fitting a sleeve washer having a cylindrical pipe-shaped portion onto a thick-walled steel pipe in the vicinity of a connecting end thereof, the thick-walled steel pipe being cut into a predetermined size in advance and having a comparatively small diameter; retaining the thick-walled steel pipe with a chuck with a head working section being left on a side which is closer to the connected end than is the sleeve washer; and working an outside circumferential surface of an end portion of the thick-walled steel pipe into a seat surface having a truncated conical shape or the truncated spherical shape corresponding to a mating seat, by a coaxial external pressure of a punch member having the shape of a connecting head, thereby forming the high-pressure metal pipe so that a cylindrical pipe-shaped portion the sleeve washer covers an outer circumferential surface of the connecting head which is of a reduced diameter and has in its inside an annular concave groove whose contour shape is shallow in depth and gentle.

The reduced-diameter connecting head which has the seat

surface having the truncated conical shape or the truncated spherical shape has a maximum outer diameter exclusive of the sleeve washer, which is larger than the outer diameter of a straight portion of the thick-walled steel pipe by 10-45%, preferably 12.5-30.0%, more preferably 15-20%.

Moreover, the sleeve washer has a pipe portion which covers the outer circumferential surface of the connecting head.

In the present invention, the reduced-diameter connecting head which has the seat surface having the truncated conical shape or the truncated spherical shape is formed to have a maximum outer diameter exclusive of the sleeve washer, which is 10-45% larger than the outer diameter of a straight portion of the thick-walled steel pipe, for the following reason: in the case of less than 10%, the sleeve washer slips and cannot fasten a fastening nut, and during the fastening of the fastening nut, the connecting head is deformed or fractured by shearing, whereas in the case of greater than 45%, the annular concave groove assumes a contour shape having a deep depth and a cross section which abruptly changes, so that a cavitation erosion easily occurs and there is a likelihood that fatigue failure occurs.

Incidentally, the length of the connecting head is not limited to a particular length, and it is suitable to make the length of the connecting head larger in view of shearing

force which acts during the fastening of the fastening nut, but an excessive length is not preferable, because a large pocket occurs.

In the present invention, since the connecting head can be reduced in diameter by the use of the sleeve washer which cover the outer circumferential surface of the connecting head, it is possible to reduce the stroke and the external axial pressure of a punch member during the formation of the connecting head, whereby it is possible to reduce the output of a forming apparatus and hence the size thereof and it is possible to change the contour shape of the annular pocket or notch to be formed in the inside of the connecting head into a contour shape having a shallow depth and a gentle cross section. Accordingly, it is possible to solve the risk of cavitation erosion due to fluid pressure in the inside of the connecting head, and moreover, it is possible to reduce the possibility that such a pocket or notch portion causes fatigue failure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will become more readily appreciated and understood from the following detailed description of preferred embodiments of the invention when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is an explanatory view, in longitudinal section,

showing a high-pressure metal pipe having a connecting head according one embodiment of the present invention, and a working process based on a method of forming such connecting head;

Fig. 2 is a longitudinal sectional view showing one embodiment of the high-pressure metal pipe formed by the connecting-head forming method shown in Fig. 1;

Fig. 3 is a longitudinal sectional view showing another embodiment of the high-pressure metal pipe formed by the method according to the present invention;

Fig. 4 is a longitudinal sectional view showing another embodiment of the high-pressure metal pipe formed by the method according to the present invention;

Fig. 5 is a longitudinal sectional view showing another embodiment of the high-pressure metal pipe formed by the method according to the present invention;

Fig. 6 is a longitudinal sectional view showing one example of a connecting head formed by a prior art forming method;

Fig. 7 is a longitudinal sectional view showing another example of a connecting head formed by a prior art forming method; and

Fig. 8 is a longitudinal sectional view showing yet another example of a connecting head formed by a prior art forming method.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the present invention, reference numeral 1 denotes a thick-walled steel pipe, reference numerals 2a to 2d sleeve washers, reference numerals 4-1 to 4-4 connecting heads having reduced diameters, reference numerals 5a to 5d annular concave grooves, reference numeral 6 a chuck, and reference numeral 7 a punch member.

The thick-walled steel pipe 1 is formed of a thick-walled pipe made of a carbon steel material which is cut into a predetermined size in advance, and the thick-walled pipe has a comparatively small diameter, for example, a diameter of 4 mm to 20 mm and a wall thickness of 1 mm to 8 mm.

In a method of forming the connecting head of the high-pressure metal pipe shown in Fig. 1 according to the present invention, the sleeve washer 2a having an approximately cylindrical pipe-shaped portion which covers the connecting head is fitted in advance into in the vicinity of the connecting head of the thick-walled steel pipe 1 with a head working section being left. This sleeve washer 2a has an approximately cylindrical enlarged-diameter portion 2a-1 which is formed to extend over approximately a half of the axial length of the sleeve washer 2a on a head-forming side, and an inclined surface 2a-2 which is approximately parallel to a seat surface of truncated conical shape around the

outside circumference surface of the enlarged-diameter portion 2a-1 at the head-forming side end opening thereof. Accordingly, when the sleeve washer 2a having this cross-sectional shape is fitted onto the thick-walled steel pipe 1, an annular space 2a-3 is formed between the inner circumferential surface of the approximately cylindrical enlarged-diameter portion 2a-1 and the outer circumferential surface of the thick-walled steel pipe 1, as shown in Fig. 1.

Then, when the end portion of the thick-walled steel pipe 1 is axially pressed by the punch member 7 with the sleeve washer 2a and the thick-walled steel pipe 1 being retained in the above-described state by the chuck 6, a portion of the head-forming section of the thick-walled steel pipe 1 plastically flows into the annular space 2a-3 of the sleeve washer 2a fitted in the thick-walled steel pipe 1 in advance, whereby the reduced-diameter connecting head 4-1 is formed. At the same time, the end portion of the thick-walled steel pipe 1 including this reduced-diameter connecting head 4-1 and the pipe-shaped portion of the sleeve washer 2a are integrated in tight contact with each other, whereby the connecting head shown in Fig. 2 is obtained. The connecting head has the reduced-diameter connecting head 4-1 whose outer circumferential surface is covered with the sleeve washer 2a, preferably, the approximately cylindrical enlarged-diameter

portion 2a-1, and has the truncated cylindrical seat surface 4-1a for a mating seat (not shown) at the end portion of the thick-walled steel pipe 1. As described previously, the outermost diameter of the reduced-diameter connecting head 4-1 is larger than the outer diameter of the straight portion of the thick-walled steel pipe 1 by 10-45%, preferably 12.5-30.0%, more preferably 15-20%. Incidentally, the sleeve washer 2a may be worked with additional caulking so that the sleeve washer 2a is far more firmly secured to the thick-walled steel pipe 1.

In this embodiment, since a portion to be worked by buckling during the formation of the connecting head is only the working section for the reduced-diameter connecting head 4-1 except the reduced-diameter portion of the sleeve washer 2a which covers the connecting head, it is possible to make the working section (buckling section) far smaller than it is in the case where the entire connecting head is formed from only the thick-walled steel pipe 1 by the prior art forming method using the large axial pressure and the long stroke of the punch member 7. Accordingly, the annular concave groove 5a which is formed around the inner circumferential surface of the connecting head by the outward expansion of the peripheral wall thereof due to buckling under the pressure of the punch member 7 has a contour shape with a shallow depth and a gentle cross section.

Figs. 3 to 5 show examples of the connecting head of the high-pressure metal pipe which is obtained by the method described above in connection with Fig. 1. In the high-pressure metal pipe shown in Fig. 3, the sleeve washer 2b having an approximately cylindrical portion which covers the outer circumferential surface of the connecting head is fitted in advance onto and fixed to the thick-walled steel pipe 1 in the vicinity of the connecting head thereof with a head working section being left, and the outside circumferential surface of the end portion of the thick-walled steel pipe 1 is worked into the seat surface 4-2a having a truncated spherical shape corresponding to a mating seat, by the coaxial external pressure of a punch member of a forming apparatus, which punch number has the shape of the connecting head. Accordingly, the structure of the high-pressure metal pipe shown in Fig. 3 is such that the reduced-diameter connecting head 4-2 **has in its inside the annular concave groove 5b whose contour shape has a shallow depth** and a gentle cross section and such that the outer circumferential surface of the connecting head 4-2 is covered with the cylindrical portion of the sleeve washer 2b.

In the high-pressure metal pipe shown in Fig. 4, similarly to that shown in Fig. 3, the sleeve washer 2c having a cylindrical portion which covers the outer circumferential surface of the connecting head is fitted in advance onto and

fixed to the thick-walled steel pipe 1 in the vicinity of the connecting head thereof with a head working section being left, and the outside circumferential surface of the end portion of the thick-walled steel pipe 1 is head worked into the seat surface 4-3a having a truncated spherical shape corresponding to a mating seat, by the coaxial external pressure of a punch member of a forming apparatus, which punch member has the shape of the connecting head. Accordingly, the structure of the high-pressure metal pipe shown in Fig. 4 is such that the reduced-diameter connecting head 4-3 **has in its inside the annular concave groove 5c whose contour shape has a shallow depth** and a gentle cross section and such that the outer circumferential surface of the connecting head 4-3 is covered with the cylindrical portion of the sleeve washer 2c so that the head-forming side end opening portion of the enlarged-diameter portion 2a-1 projects into the side of the seat surface 4-3a in the form of a small visor.

In the high-pressure metal pipe shown in Fig. 5, the sleeve washer 2d which has an approximately cylindrical portion to cover the outer circumferential surface of the connecting head and has at its rear end portion the sleeve 2d-1 to come into tight contact with the thick-walled steel pipe 1 is fitted in advance onto and fixed to the thick-walled steel pipe 1 in the vicinity of the connecting head thereof with a head working section being left, and the outside

circumferential surface of the end portion of the thick-walled steel pipe 1 is worked into the seat surface 4-4a having a truncated spherical shape corresponding to a mating seat, by the coaxial external pressure of a punch member of a forming apparatus, which punch member has the shape of the connecting head. Accordingly, the structure of the high-pressure metal pipe shown in Fig. 5 is such that the reduced-diameter connecting head 4-4 **has in its inside the annular concave groove 5e whose contour shape has a shallow depth** and a gentle cross section and such that the outer circumferential surface of the connecting head 4-4 is covered with the cylindrical portion of the sleeve washer 2d.

As described above, in accordance with the high-pressure metal pipe having a connecting head according to the present invention as well as the method of forming the connecting head, since the connecting head can be reduced in diameter by the use of a sleeve washer having a cylindrical portion to cover the outer circumferential surface of the connecting head, it is possible to reduce the stroke and the external axial pressure of a punch member during the formation of the connecting head, whereby it is possible to reduce the output of a forming apparatus and hence the size thereof and it is possible to change the contour shape of an annular pocket or notch to be formed in the inside of the connecting head into a contour shape having a shallow depth and a gentle cross

section. Accordingly, it is possible to solve the risk of cavitation erosion due to fluid pressure in the inside of the connecting head, and moreover, it is possible to achieve the superior advantage of greatly reducing the possibility that such a pocket or notch portion causes fatigue failure.